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REVIEW OF BRIDGE VIBRATION AND FUTURE DIRECTION

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The objective of this review paper is to sum up all the topics related to conventional and integral bridge vibration and focus the effects of scour on conventional and integral bridge and finally to suggest future directions of research and innovation. Research on separate issues on bridge vibration, integral bridge vibration, scour on bridge and scour on integral bridge are well emphasized. Issues of local scour on vibration still not been explored in the research. The future direction and innovation are highlighted in the future research on conventional and integral bridge vibration related to localized scour to fill the gap of the research.

1. Introduction

Engineers expanded the skill to perceive structural damage in a bridge before it endangers the structure. Bridge condition evaluation is mostly carried out by visual inspection at intervals of one to five years, followed by more detailed examination and analysis. On the other hand, it is probable for significant damage to have developed and putting structures at risk. Catastrophic failures of bridges due to undetected progressive damage in the past were detected. Developments in electronics and data processing technology have made continuous monitoring a realistic tool and it should provide cost effective, automated bridge monitoring solutions to detect these conditions. (Yeunga and Smithb [1]

Doebling et al. [2] reconsidered the principal methods that have been developed to modal frequencies and mode shapes, on top of methods based on changes to the measured flexibility matrix or finite element model. Moreover, considerable theoretical and experimental progress has been made in the detection and location of damage by dynamic methods.

It is probable to identify hidden cracks, scouring and fractures, according to bridge engineers by observing and monitoring changes in vibrations of bridges. It's not always possible to see damage to a bridge, but using vibrations it is possible to 'see' what can't be seen.

Structural engineers preferred to design integral bridge compared to conventional bridge since it reduces in initial construction cost, and in long-term maintenance expenses, improves seismic resistance, and extends long-term serviceability (Kunin and Alampalli, [3]). Most of the previous researches concentrated on the piers, abutments, or combined piles separately. Concept of integral bridge is like a portal frame, and where scour is a natural phenomenon caused by the interference of the bridge with the flow. Research on bridge scour is extensively reported in previous scour studies. Studies on scour at abutments, piers, and piles are available separately, but combinations of superstructure and sub-structure of the bridge need to be investigated. Laboratory studies are needed to develop an alternate additional design method for improving scour countermeasures. Furthermore, scour predictions equations can be improved according to the real situation in the river.

The main directions of present review paper are the vibration analysis of traditional bridges, where it will cover all the studies related to the use of the vibration testing carried on bridge for health monitoring. The next direction is the studies related to the vibration analysis of the integral bridge, where integral bridges start to be used nowadays in order to overcome some of the traditional bridges and to minimize the costs. Since the scour is very important phenomenon which it can happen anywhere and anytime to the bridges, and it change the boundary conditions of the bridges and influence the physical behavior of the bridge, so it may cause bridge collapse. The importance of study of scouring phenomenon and related to the vibration are needed. Future study will present studies on the souring with related to the traditional bridges as well as integral bridges vibration. The future direction which suggested by present review study, based on the gap or the shortage in existing studies with related to the integral bridges vibration testing in order to detect the scouring and to investigate the influence of the vibration of the integral bridges on the scouring phenomenon and vice versa.

2. Bridge Vibration

There are a great number of existing studies deal with the vibration test of the bridges. Some of them deal with different design of the bridges, and some related to monitor the effect of different parameters on the bridge such as cracks, temperature, fatigue, bearing isolation and it is influence on the vibration testing. Vibration of long-span bridges, especially of cable supported steel bridges, is often decisive in the design and construction of these bridges. Review of the vibration of long-span bridges due to motion-dependent forces typically due to winds and the control methods with emphasis on research, development and practice in Japan have been done by Fujino [4]. Jeong-Tae Kim et. al. [5] studied a vibration-based damage monitoring scheme to warn about the occurrence, the location, and the severity of damage under temperature-induced uncertainty conditions was proposed. Both damage localization and damage-sizing results were very accurate when pre-damage frequencies and post-damage frequencies were obtained from the same temperature conditions. In contrast, this accuracy decreased as the temperature gap increased.

Cornwell et al. [6], Farrar et al. [7], Peeters et. al. [8], Kim et al. [9], and Ni et al. [10] conducted widespread experiments on the variability of the dynamic properties of bridges caused by changing temperature conditions. They endeavoured to correlate modal properties with temperature, and also to expand system identification models that could divide the influences of temperature from true indications of damage on dynamic modal parameters. Yeunga and Smithb [1] in them study for perceiving the onset of damage in bridges has been developed, using the dynamic response spectrum appraised from nonstop monitored instruments, together with neural networks for pattern recognition. Finally, a dependable damage identification rate of about 70% could be attained even with a modest amount of noise added to the dynamic response signals.

Brownjohn et al [11] performed an ambient vibration survey of the Humber Bridge in July 2008 by a team from the UK, Portugal and Hong Kong. obtained using three techniques, natural excitation technique/Eigen system realization algorithm, stochastic subspace identification and poly-Least Squares Frequency Domain method, are compared among themselves and with those obtained from a 1985 test of the bridge, showing few significant modal parameter changes over 23 years in cases where direct comparison is possible. The parameter approximates display significant variability between different methods and variations of the same method, while also varying in time and having inherent variability. Bridge vibration is quite well known and many studies have been done, and many parameters have been investigated. New technologies have been used for monitoring of bridges conditions.

3. Integral Bridge Vibration

Integral bridge is still new type of structure start to be used widely, and its behaviour is slightly different from traditional bridges, where substructures are integrated together in form of integral bridges. As mentioned, there are still gap in the literatures and researches although some work have been done. Assessments and measurements of vibration-based damage detection for an integral abutment bridge have been done by Siddique et al [12]. It was found that localized damage to the top concrete cover of the bridge deck could be reliably detected and located if the sensors were located sufficiently close to the damage and if uncertainty in the mode shapes was attenuated through the employment of a adequate number of repeated testings

Real-time wireless vibration monitoring for functioning modal analysis of an integral abutment highway bridge have been done by Matthew J. Whelan et. al. [13]. Remote structural health monitoring systems utilizing a sensor-based quantitative assessment of structural condition are perceived as the future in long-term bridge management programs. The study found that the use of the stochastic subspace identification SSI techniques to approximate modal parameters from output only experimental data has been found to be preferable to the Frequency Domain Decomposition FDD method despite the increased computational attempt and subjectivity required to recognize system poles.

Figure 1 shows the integral bridge located at Potsdam, N.Y and was used by Matthew J. Whelan et. al. [13] to carry out the real time monitoring. Figure 2 shows the time window of the accelerations at the traffic event after conducting the time monitoring. During execution of Frequency Domain Decomposition FDD modal analysis, a 4096- point average normalized power spectral density was calculated using the time histories from all test series and sensor locations (Fig. 3). Natural frequencies were selected from the modal peaks in attendance of the power spectrum and the corresponding mode shapes were derived for each test sequence.

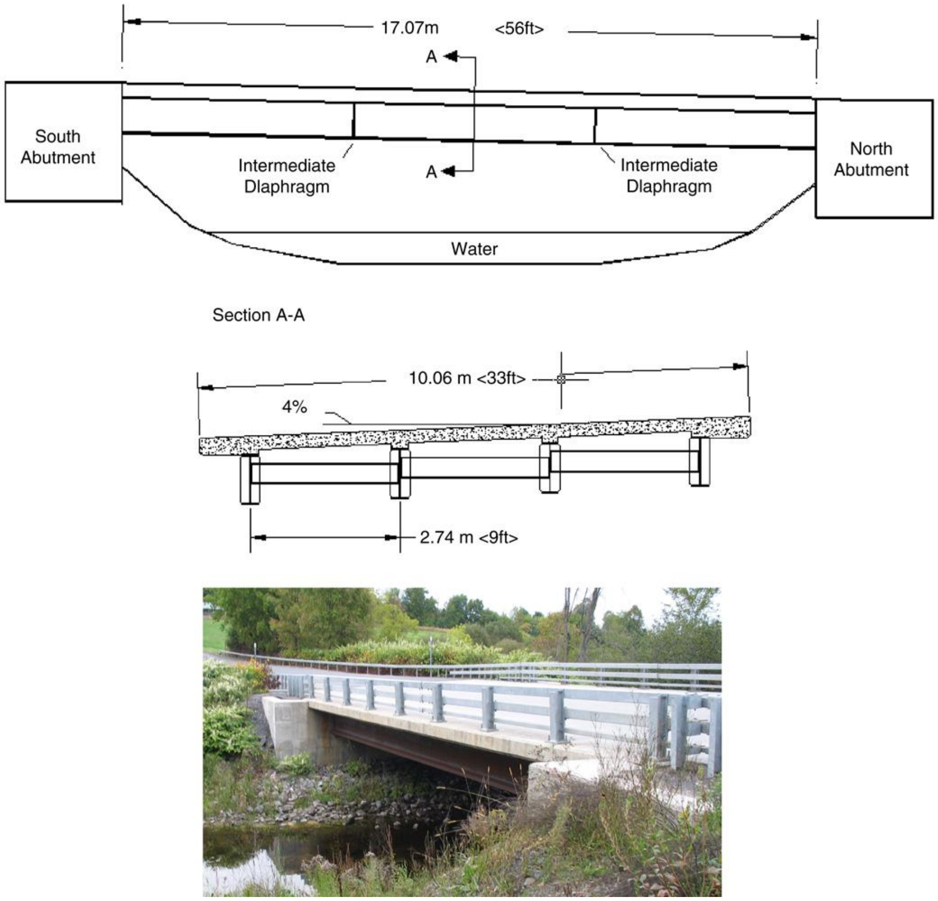

Figure 1: Integral bridge in Potsdam, N.Y. used by Whelana [13], for real time monitoring.

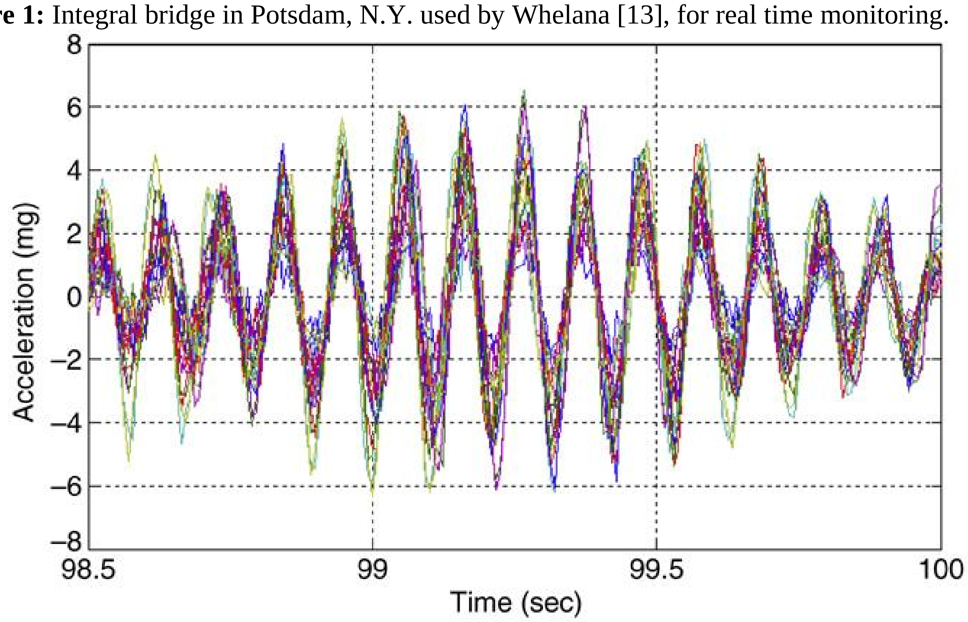

Figure 2: Time window overlay of accelerations during a traffic event.

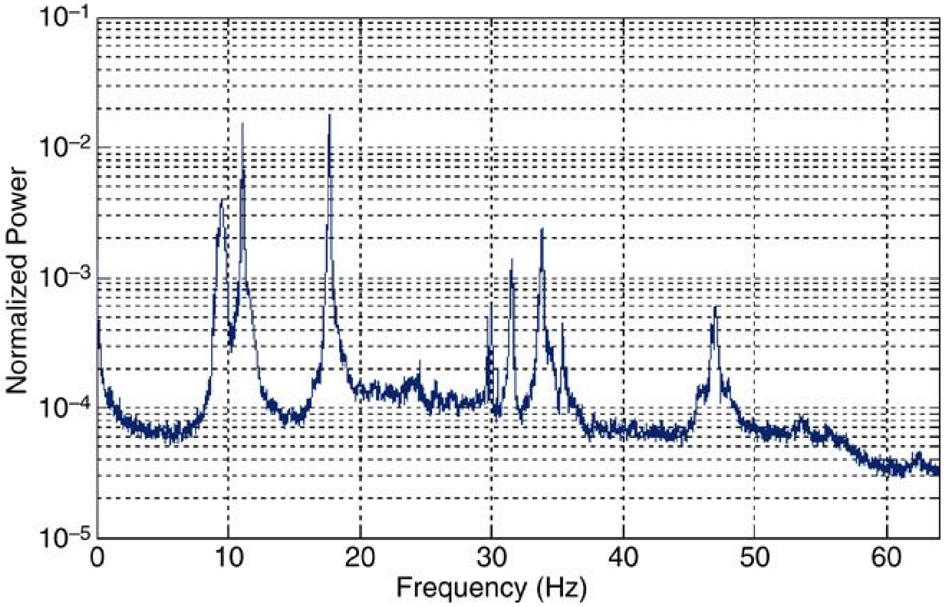

Figure 3: Average normalized power spectral density

Research and study of over 500 bridge failures conducted by Wardhana and Hadipriono [14], considering events from 1989 to 2000 concluded that the common of failure instances occur due to a triggering event. In meticulous, short-term hydraulic events, long-term scour, collision, and overload were sighted for 73% of the documented collapse, while deterioration of structural members, design flaws, and construction-related issues resulted in nearly 12% of the failures. Response from a sensor-based monitoring system would pre-emptively signal such deterioration to allow a plan of refurbish or closure prior to unsafe operation.

A review of recent wireless sensor operations for integral bridges health monitoring (Pakzad et. al. [15], Paek et. al. [16] , Lynch et. al. [17])reveals that the networks have generally relied on either local data logging and post-sampling transmission of sensor data or on low sampling rates and/or limited numbers of sensors in order to concentrate on transceiver bandwidth limitations. Such allowances severely limit the flexibility and ability of a structural health monitoring system in terms of sampling period, data acquisition rates, and spatial resolution as well as quality of the derived mode shapes.

A simplified method for the free vibration and flutter analysis of integral bridge decks was presented by Banerjee [18]. An analytical method for the free vibration and flutter analysis of bridge decks is obtainable by deriving explicitly each term required for the whole analysis. The method is free from ill-conditioning problems usually associated with complex (numerical) matrix manipulation. The flutter speed and frequency of three illustrative examples of integral bridge decks have been demonstrated by using the proposed method. It is clearly seen that this field needs more investigation to discover the integral bridge vibration, and to study the factors influence the vibration analysis of the integral bridges and the effect of the integral bridge vibration due to the traffic movement on the integral bridge substructures and also scouring phenomenon.

4. Scour on Bridge

Precedent explorations on the local scour at abutments, piers and its effect on flow intensity, flow shallowness, sediment coarseness and time are reviewed in this section. It also highlights the influence of the velocity distribution for bridge piers. Several researchers have come out with design equations to forecast the scour progress. Underestimation of the scour depth would lead to uneconomical repairs expenses in the future. Ali and Karim [19], Ansari *et al* [20], Coleman [21], Dey and Raikar [22], Dey *et al* [23], Elliott and Baker [24], Melville [25], Melville and Raudkivi [26] , Melville and Sutherland [27], Melville and Dongol [28], Parola *et al* [29], Raudkivi and Ettema [30], and Richardson and Panchang [31] conducted several studies on the local scour at piers. Local scour at abutments were studied by Dey and Barbhuiya [32], and Sturm [33]. Oliveto and Hager [34] investigated the local scour study on both bridge piers and abutments. Sumer and Fredsoe [35] concentrated the local scour study on piles of the bridge.

Scour is defined as the hole left at the back when sediment is flowed away from the foundation of a river. Scour progress is strong during floods. Fast flowing water has more force than calm water to raise and bring sediment down the river (Melville and Coleman,[36]). General or degradational scour is the general elimination of sediment from the river base by the flow of the river. This sediment removal and resultant of lowering of the river bottom is a usual progression, but may remove great amounts of sediment over time (Warren,[37]).

5. Integral Bridge Scour

Literature reviews on local scour are very well documented by previous investigators. Over the recent years, integral bridges have become increasingly well-liked. Integral bridges have become a cost-effective alternative and have longer life spans than their complements because of the difficulties and costs associated with failed expansion joints in the conventional bridges. The increasing use of integral bridge has highlighted the need for more information and guidance in modern bridge design. An algorithm based on a nonlinear finite element procedure was extended and employed by Greimann, et. al. [38], to study the piling stresses and pile-soil interaction in integral abutment bridges which influence the scouring phenomenon.

Akib, S. et al [39] and [40] presented an experimental work to develop a contour plots for integral bridge scour and compared the results of the scour behaviour on single and double row pile integral bridges. They found that the scour was more severe at double row pile integral bridge since the water flowed faster between the gap of the two piles. The study was extended to examine the effects of multiple span integral bridge in relation to scouring phenomenon (Akib et al,[41]). Review of existing studies on the scouring of integral bridges shows that this field need more investigation and need deeper study on the relationship between the scour phenomenon and integral bridge behaviour.

6. Future Directions

This review paper elaborated the bridge vibration issues and highlighted the innovation and future research. The future direction which suggested by present review study , based on the gap or the shortage in existing studies with related to the conventional bridges vibration testing in order to detect the scouring, or the effects of scouring action on the vibration of the bridge. In addition, an investigation the influence of the vibration of the integral bridges on the scouring phenomenon is also encouraged since the behavior of integral bridge is rigid and different from the conventional bridge. Effects of different types of sediments also would be a possible new area of research to study the vibration effect on integral bridge scour.

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